pincushion millipedes have been reported as feeding on algae and occurring mainly in crevices in rocks, and under stones, leaf-litter and the bark of trees.

The Hamersley Range species has been observed in considerable numbers under rock flakes in spinifex (*Triodia*) dominated areas. Its activity has been noted as usually commencing after sunset and continuing for a few hours. Plagues have been encountered at Wittenoom in April and May 1973, February 1976, May 1977, and October 1983. At Tom Price 'countless millions' were present in February 1978, November 1982 to January 1983, and July 1983. These millipedes have invaded many buildings including living quarters. They appeared to be activated by rainfall, and their moving ranks travelled over their numerous dead on soil which was superficially flooded and even over ground that had been treated with insecticides. In spite of their intermittent appearance in plague proportions, very little is known of their life cycle and natural history. I would appreciate receiving any findings about the pincushion millipedes of the Hamersley Range and specimens (preserved in alcohol or methylated spirits) from other areas.

ACKNOWLEDGEMENTS

Information regarding the activity of these millipedes in the Hamersley Range has been provided by a number of persons including E.N. Wahl, L. Styles, W.D. Temperton, C.E. Chobanoff, M. McKay, K. Campbell, A. Davies, D. Talbot and N. Bolton.

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BIRD POPULATIONS OF FARM PLANTATIONS IN THE HOTHAM RIVER VALLEY, W.A.

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INTRODUCTION

About 50% of the Hotham River catchment was cleared by 1973, leading to significant saltland development (Peck and Hurle, 1973). Farm plantations were established in early winter 1976 at three locations in the catchment. Twenty-five species of trees and shrubs were evaluated over six or seven years for survival and growth near salt seeps (Biddiscombe *et al.*, 1985). It was assumed that successful afforestation would control salt seepage. The main objective of this paper is to describe the increase in bird species and numbers with the growth of plantations. The results may indicate the value of the plantations to surviving local avifauna which depend largely on small areas of uncleared forest and woodland. There appears to be no published report on avifauna in young farm plantations in Western Australia.

METHODS

Sites

Two plantations were 120 m apart on a gentle, partly-cleared slope at Bannister and two were on cultivated slopes near salt scalds at Dryandra and Popanyinning (Fig. 1). The subcatchments had been cultivated for 10 years (Bannister) to 50 years prior to the planting. The locations spanned about 90 km and 800 to 440 mm annual rainfall (80 to 85% in the wet season of May to

October). Nearby relict vegetation differed between locations (Fig. 2): jarrah - marri (*Eucalyptus marginata - E. calophylla*) State Forest at Bannister, a wandoo (*E. wandoo*) woodland Reserve at Dryandra and small patches of disturbed heath and wandoo - *Casuarina - Acacia* communities at Popanyinning. The State Forest, Reserve and tree clumps (Popanyinning) were 0.5 km distant from the respective plantations (Fig. 2).

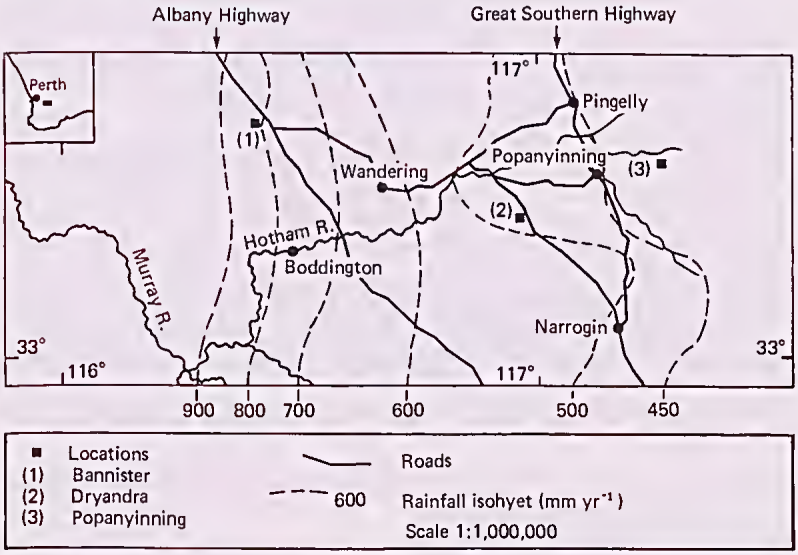

Figure 1. Location of plantations; average rainfall.

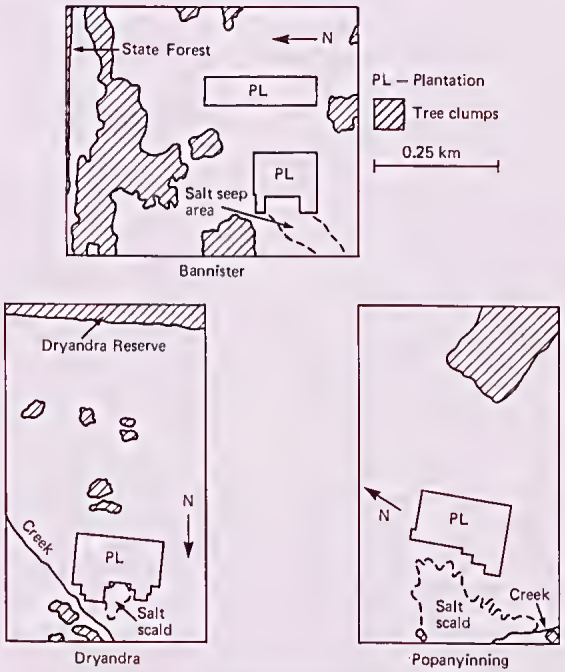

Figure 2. Maps of plantations and nearby vegetation; drawn from vertical aerial photographs.

Plantation species, design and measurements were described by Biddiscombe *et al.* (1981, 1985). The main species were eucalypts of forest and woodland form from coastal and inland southern Australia. Eight of these species formed the bulk of all plantations for 7 years. All plantings were based on a 3.5 x 3.5 m grid, providing about 800 plants per hectare. The afforestation covered 2.5 to 3 ha per location including access laneways and plantations were rectangular with the longest side on contour. Pasture of the fenced area was not grazed for 18 months after planting but was controlled in most subsequent seasons by intermittent sheep grazing. Tree height, crown diameter and height of crown base were measured once a year in autumn-early winter. Plantation crown cover was the average crown area (π x radius^2) of all species as a percentage of the planting grid (12.25 m^2).

Avifauna

Identification was based on Slater (1970, 1974). Counts of each species in 1976-83 were made by a single observer during a half-hour traverse on foot, moving about centrally along the length of a plantation. All traverses were done between 10 a.m. and noon, irrespective of time of year. The distance of a traverse varied from 125 m (midslope) and 210 m (upslope) at Bannister to about 170 m at the other locations.

Width of transect was 30 m, being one plot of a tree species on both sides of the observer. The direction of traverse was repeated at each sampling. Counts from the midslope and near-divide plantations at Bannister were combined on each occasion because birds were observed to move frequently between the

Table 1. Presence of species (%) at 3 locations, May to October period. Weighted mean of 4 years, 1979-82.

Species	Bannister	Dryandra	Popanyinning
Australian Shelduck, *Tadorna tadornoides*	-	28	6
Australian Kestrel, *Falco cenchroides*	-	12	8
Common Bronzewing, *Pheps chelcoptera*	53	79#	33
White-tailed Black-Cockatoo, *Calyptorhynchus*	6	-	-
Red-tailed Black-Cockatoo, *Calyptorhynchus*	6	-	-
Western Rosella, *Pletycercus icterotis*	64	29	14
Port Lincoln Ringneck, *Barnardius zonerius*	79#	52	56
Red-capped Parrot, *Purpureicephelus spurius*	3	-	-
Elegant Parrot, *Neophema elegans*	5	11	6
Pallid Cuckoo, *Cuculus pallidus*	17	17	17
Tree Martin, *Petrochelidon nigricans*	-	35	53
Richard's Pipit, *Anthus noveeseelandiae*	12	76#	82#
Australian Magpie-lark, *Grelline cyanoleuca*	-	11	-
Black-faced Cuckoo-shrike, *Coracina papuensis*	9	6	9
Western Gerygone, *Gerygone fusca*	-	8	20
Weebill, *Smicrornis brevirostris*	82#	56	88#
Yellow-rumped Thornbill, *Acanthiza chrysorrhoa*	78#	80#	56
Western Thornbill, *Acanthiza inorneta*	83#	77#	82#
Scarlet Robin, *Petroica multicolor*	77#	9	59
Western Yellow Robin, *Eopsaltria griseogularis*	6	5	6
Grey Fantail, *Rhipidura fuliginosa*	77#	3	11
Willie Wagtail, *Rhipidure leucophrys*	62	78#	82#
Golden Whistler, *Pechycephale pectoralis*	23	32	56
Grey Shrike-thrush, *Colluricincle harmonica*	21	6	15
White-fronted Chat, *Ephthianura albifrons*	11	14	88#
Silvereye, *Zosterops laterelis*	17	-	-
Brown Honeyeater, *Lichmera indistincta*	97#	97#	89#
Western Spinebill, *Acenthorhynchus superciliosus*	18	27	11
Singing Honeyeater, *Meliphega virescens*	82#	82#	97#
White-cheeked Honeyeater, *Phylidonyris niger*	33	53	15
Red Wattlebird, *Anthochaera carunculata*	85#	91#	89#
Black-faced Woodswallow, *Artamus cinereus*	-	15	22
Dusky Woodswallow, *Artamus cyanopterus*	25	15	59
Australian Magpie, *Gymnorhina tibicen*	9	12	3
Australian Raven, *Corvus coronoides*	18	27	32

° *Some English names after RAOU (1978).*
\# *Frequent species.*

two. The census total from 1976 to 1978 was five or six per wet season. This was increased to eight or nine at about 3 weekly intervals during 1979-82. Sample number for the summer-autumn observations of all years varied from two (December, March) to six (monthly).

Popanyinning plantation was not surveyed after April 1983 because part of the plantation was damaged by fire, but other plantations were surveyed five times between May and September. To obtain comparisons across locations, sampling was completed within a period of four or five days.

Presence of species was estimated as the proportion of occurrences within wet-season censuses; species with presence 75% (weighted mean) in these surveys and a sighting in at least two dry-season surveys from 1979 onwards were classified as frequent. A presence of 50 to 75% in the wet season was designated as occasional and 50% was rated as rare. Rare sightings of other species from non-census visits were also listed.

RESULTS

Species

Thirty-five species were recorded in censuses of the wet seasons of 1979-82, 13 of these being given frequent status (Table 1). The percentage presence of frequent species at Bannister and Dryandra in 1983 was similar to that shown for the same species in Table 1. Red Wattlebirds, Brown Honeyeaters, Singing Honeyeaters and Western Thornbills shared frequent presence with Common Bronzewings, Port Lincoln Ringnecks, Weebills, Scarlet Robins, Yellow-rumped Thornbills, Grey Fantails, Willie Wagtails, Richard's Pipits and White-fronted Chats in one or other plantation. Five species of the groups also showed occasional status in one or more plantations. Few species of the

Table 2: Seasonal occurrence and activities of rare sightings during non-census visits, 1977-82.

Species °	B	D	P	Activity
Emu, *Dromais novaehollandiae*	Sp	-	-	Fp
White-faced Heron, *Ardea novaehollandiae*	W	-	-	S
Australian Goshawk, *Accipiter fasciatus*	Sp,Sm	-	Sp	Fl*
Wedge-tailed Eagle, *Aquila audax*	Au,W	Sm	Sm	Fp*
Brown Falcon, *Falco berigora*	Sp	W,Sp	-	Fp*
Stubble Quail, *Coturnix pectoralis*	Sm	Sm	-	Fp,S
Banded Lapwing, *Vanellus tricolor*	Sp	-	-	Fp
Black-fronted Dotterel, *Charadrius melanops*	W	-	Sp	Fp
Galah, *Eolophus roseicapilla*	-	-	Au	Fl
Mulga parrot,*Psephotus varius*	-	-	W	Fp
Southern Boobook, *Ninox novaeseelandiae*	-	-	Sm	S
Laughing Kookaburra, *Dacelo gigas*	W	W	-	Fp
Rainbow Bee-eater, *Merops ornatus*	Sp,Sm	Sp,Sm	Sp,Sm	Fl
White-backed Swallow, *Cheramoeca leucosternum*	-	Au	-	Fo
Welcome Swallow, *Hirundo neoxena*	Sp,Sm	Sp,Sm	Sp,Sm	Fo
White-winged Triller, *Lalage sueurii*	Sm	-	-	Fh
Splendid Fairy-wren, *Malurus splendens*	Au,W	-	-	Fp
Brown Songlark, *Cinclorhamphus cruralis*	-	Sm	Sm	Fp
White-browed Scrub-wren, *Sericornis frontalis maculatus*	-	W	-	Fl
Restless Flycatcher, *Myiagra inquieta*	W	-	Fl	
Rufous Whistler, *Pachycephala rufiventris*	-	W	-	Fl
Rufous Treecreeper, *Climacteris rufa*	Sm	-	-	Fl
Spotted Pardalote, *Pardalotus punctatus*	Au,W	-	W,Sp,Sm	Fl,Fo
Striated Pardalote, *Pardalotus substriatus*	W,Sp,Sm	W,Sp	W	Fl,Fh
Grey Butcherbird, *Cracticus torquatus*	-	-	Au	Fl*
Grey Currawong, *Strepera versicolor*	-	W	Au	Fl

B,D,P - Bannister, Dryandra, Popanyinning locations.
Au - autumn, W - winter, Sp - spring, Sm - summer
F - feeding (* predatory on birds): p - in pasture, l - in low tree crowns,
h - in high tree crowns, o - above tree crowns.
S - sheltering in tree crowns.

period were restricted to one location, the examples being White-tailed and Red-tailed Black-Cockatoos, Red-capped Parrots and Silvereyes at Bannister and Magpie-larks at Dryandra. During each of the first three years from planting the only frequent species were Richard's Pipits (range 80 to 85%) and White-fronted Chats (80 to 100%) in all plantations; data for other species of the period are available from the author.

Rare occurrence of 26 species noted from all non-census visits to all plantations is given in Table 2. Species included wide-ranging endemic Falconiformes and Psittaciformes, Dicaeidae (three species of pardalotes), and migrant Welcome Swallows and Rainbow Bee-eaters, many of these being sighted in summer.

Population Size

Census counts are presented in Fig. 3. Population size showed seasonal variation, building to a maximum by July or August every year. There was a steady decline during spring and midsummer numbers were generally low. Peak numbers at Bannister and Dryandra doubled during the third year after planting and then became fairly static to 1982. Numbers at Popanyinning were not high until 1981. The highest population was counted at Bannister in August 1983.

Bannister plantations together tended to have higher peak numbers than Dryandra plantations in all years except 1980. Popanyinning produced lower peaks than Dryandra until reaching parity in 1982.

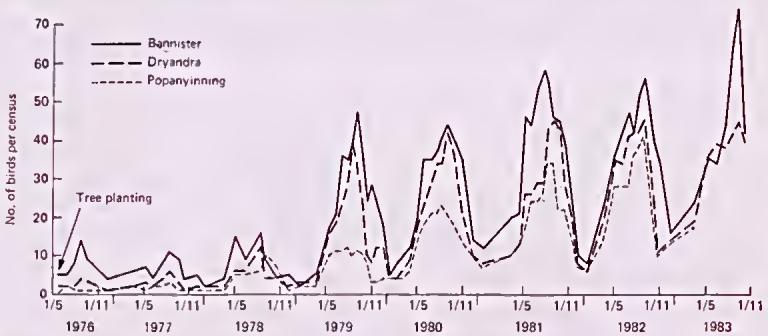

Figure 3. Population of birds at each census, 1976 to 1983.

Progressive growth of the plantations was described by Biddiscombe *et al.* (1985) and yearly means of tree height and crown cover are presented here in Fig. 4. The increase in bird numbers at Bannister in 1979 was associated with trees about 4 m tall, crown cover nearly 50% and crown bases of most species still near ground level; by 1982 many crowns were interlacing but had lost their leaves to a height of 2 m. Trees at Dryandra in 1979 were little more than half the height and crown cover of those at Bannister, but at least a year ahead of Popanyinning trees in these dimensions. Most species at Dryandra and Popanyinning retained non-interlacing, moderately leafy, low crowns (bases 0.5 to 1 m aboveground) to 1982, while bird numbers in wet seasons were increasing markedly at the latter location (Fig. 3).

Species Composition of Populations

Frequent species listed in Table 1 made up 67 to 80% of the peak winter numbers in 1979-82, as illustrated in Fig. 5. The highest contributors within plantations by 1982 included Red Wattlebirds at all locations, Brown Honeyeaters at two and Port Lincoln Ringnecks and White-fronted Chats at single locations.

Summer populations from 1980 onwards usually included only one or two individuals of frequent species of the preceding winter and spring.

Food Resources

Frequent (autumn, winter, spring) and abundant flowering of trees such as yellow gum (*Eucalyptus leucoxylon*), coastal moort (*E. platypus* var. *heterophylla*), swamp mahogany (*E. robusta*), sugar gum (*E. cladocalyx*) and river gum (*E. camaldulensis*) was an obvious attraction for honeyeaters and

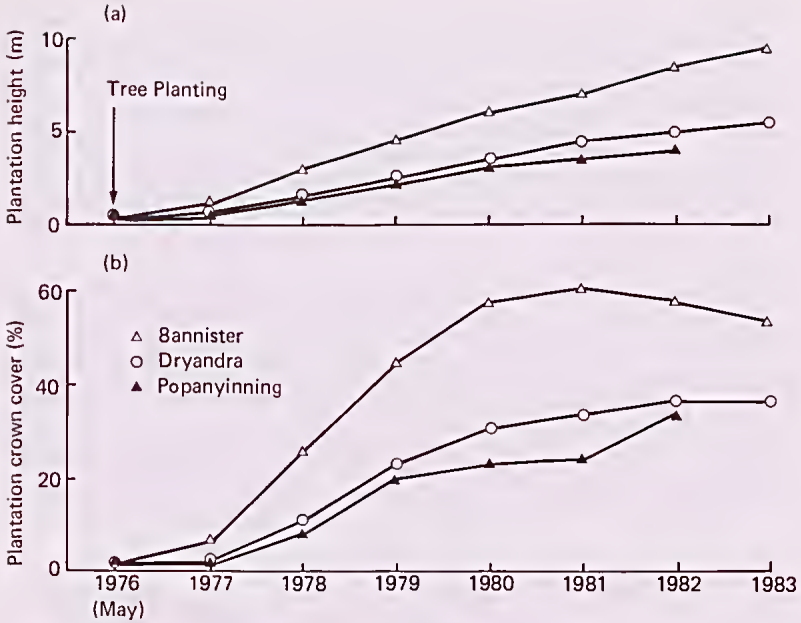

Figure 4. (a) Plantation height, (b) Plantation crown cover.

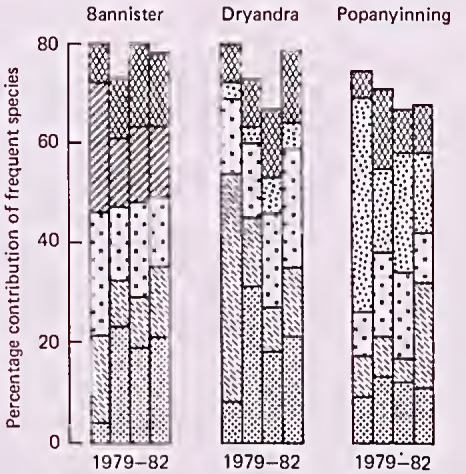

Figure 5.

Thornbills (Western and/or Yellow-rumped)
Red Wattlebirds
Honeyeaters (Brown and Singing)
Ringneck Parrots
Pipits and/or White-fronted Chats
Other frequent species of plantation (see Table 1)

Figure 5. Species composition of peak winter populations, 1979 to 1982.

Red Wattlebirds at all locations. Yellow box (*E. melliodora*) flowered profusely after three years and appeared to be a favoured source of nectar; other eucalypts flowered sparsely from 1979 and their inflorescences were often searched by honeyeaters. Parrots fed on the buds of most eucalypts. Considerable populations of insects were present at times in the wet season, including leaf-eating beetles, caterpillars and sawflies, sucking insects and wood borers associated with eucalypts in south-western W.A. (Curry and Moulden 1981). Pasture patches and tree leaf litter were often explored by insectivorous species, particularly Yellow-rumped Thornbills, Scarlet Robins, Richard's Pipits and White-fronted Chats. Honey bees sampled all flowering trees and were seen frequently to be eaten by Red Wattlebirds. Grasshoppers and ants were common in the plantations in the dry season.

Nesting

In the period from 1977 to 1982, 18 nests were discovered in the plantation area at Bannister and 23 were found at each of the other locations (Table 3). Most nests belonged to frequent species, especially White-fronted Chats and Richard's Pipits which used ungrazed pasture and/or dense, low tree crowns in the early stages. Examples of these trees were coastal moort, wandoo and merrit (*E. flocktoniae*). Yellow-rumped Thornbills were next to begin nesting (1978), preferring dense crowns of *Casuarina obesa*. Brown and Singing Honeyeaters' nests were first recorded in 1979; these were followed in 1980 by Red Wattlebird nests at heights of 2 to 3 m in spreading trees such as those of salt river gum (*E. sargentii*) and swamp mallet (*E. spathulata*). Fledglings of all nesting species (Table 3) were seen from late winter to spring.

Table 3: Nesting and breeding observations, 1977-82.

Species	Nest location and number	Breeding success Total eggs#	Fledglings seen °
Black-fronted Dotterel	P-1	3	-
Common Bronzewing	B-1,D-1,P-1	7	o
Pallid Cuckoo	D-1	1	-
Richard's Pipit	B-1,D-2,P-1	15	o
Weebill	P-1	2	-
Yellow-rumped Thornbill	B-5,P-1	17	o
Scarlet Robin	B-1	3	o
Grey Fantail	B-1	3	o
Willie Wagtail	D-2,P-1	9	o
White-fronted Chat	B-2,D-6,P-14	76	o
Brown Honeyeater	B-5, D-1	22	o
Singing Honeyeater	D-5	17	o
Red Wattlebird	D-5,P-3	24	o
Dusky Woodswallow	B-2	7	-

B,D,P - Bannister, Dryandra, Popanyinning locations
All nests, all locations

DISCUSSION AND CONCLUSIONS

Bird species and numbers were probably affected most by the proximity of the plantations to inhabitants of uncleared vegetation. Although nearby relict vegetation was scattered at Popanyinning, a useful if slow winter invasion of the plantation took place. All species of the location (Table 1) except two (White-fronted Chat, Dusky Woodswallow) were recorded by Harold and Dell (1979) in Yornaning Nature Reserve, 20 km to the east-south-east. Lists for Dryandra State Forest and Northern Jarrah-Wandoo Forests (W.A. Forests Department, 1974) also included all species shown in Table 1; Nichols and Nichols (1984) noted the Bannister group of Table 1 in Mount Saddleback State Forest about 22 km to the south, with the exception of White-tailed Black-Cockatoos and White-fronted Chat. No data are available for tracing avifauna changes in these Reserves and Forests during 1976-83.

Area of replanting, by affecting food, shelter and nesting resources, may have been an important factor. For example, tall eucalypt woodlots covering 10 ha near State Forest of southern N.S.W. harboured 90 to 100 individuals in

autumn and spring 1983 (Recher *et al.* 1983), or double the highest peaks recorded for most wet seasons at Bannister (Fig. 3). Small trees were sufficient to promote the first invasions but a crown cover of about 25%, achieved at Bannister in 1978 and at other locations between 1979 and 1981 (Fig. 4), may have stimulated the subsequent rises in winter populations. Nesting potential in high crowns could increase in the long term, whereas during the study a shortage of nesting sites appeared to encourage an exodus of some thornbills and parrots by early spring when food and moisture were still plentiful. Lack of water within the plantation areas discouraged summer presence. Sedgwick (1949) considered that moisture rather than food supply or temperature governed the movement of many of the species of Table 1 in low rainfall areas of the W.A. eastern wheatbelt.

Local endemics from widely separated communities, nomads and migrants were among the visitors. The survey suggests overall that widespread replanting of woodlots would be exploited by local extant populations, fitting in with strong urges for seasonal movement (Nix 1976). This afforestation needs to be within territorial reach and to present frequent flowering and mixed structure for the benefit of small birds in particular. Exotic pine plantations in moderate rainfall are known to attract few species (Friend 1982) and may best be alternated with eucalypt woodlots to provide suitable corridors.

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